8.2 Conductors and Fields

You will now examine how conductors are used in the transport of electric current and electromagnetic signals. An electric field can be established not only in the spatial region around point charges or in the air gap between parallel plates, but also in the metal conducting wires that enable electric current to be transmitted. Shielded coaxial wires can also be used as a "guide" to transport electromagnetic waves to a convenient location (such as your television receiver) with minimal loss of strength. You will learn more about electromagnetic waves in Unit 4, but for now, you can at least gain a qualitative idea of how they can be transported efficiently, with minimal loss of energy.

SECTION EXPECTATIONS

- Define and describe the concepts related to electric fields.
- Describe and explain the electric field that exists inside and on the surface of a charged conductor.
- Demonstrate how an understanding of electric fields can be applied to control the electric field around a conductor.

KEY TERM

- Faraday cage

Conducting Wires

In previous science courses, you worked with conducting wires and circuits. You learned that if you placed an electric potential difference across the ends of the conductor, a current would flow. You have just learned that an electric potential difference creates an electric field and that charges in an electric field experience electric forces. Now you can examine conductors in more detail.

In previous studies, you learned that the copper atoms have heavy positive nuclei and a cloud of negative electrons surrounding it. An isolated atom has electrons filling up the lower energy "shells," but there are also a few electrons outside of these complete shells. These outer electrons can move relatively easily if they are replaced with another electron from another copper atom. The electrons are then free to move through the metal, colliding randomly with the stationary positive nuclei.

If a battery is connected to the ends of a metal wire, it will create an electric field inside the wire and parallel to its axis. Consequently, the free electrons will move in a direction opposite to the direction of the field, as shown in Figure 8.7.

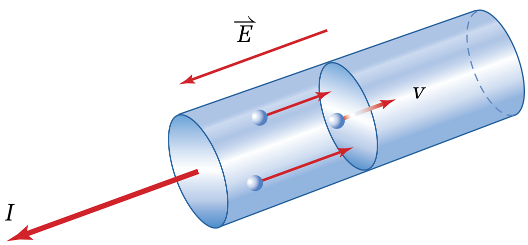

Figure 8.7 In a conductor, electrons move opposite to the direction of the electric field, because the direction of the field is defined as the direction in which a positive charge would move.

Hollow Conductors: Faraday's Ice-Pail Experiment

When you carried out the Cover It Up activity in the Multi-Lab at the beginning of this chapter, you probably noticed that when you placed the can over the sphere on the electroscope, it eliminated the effect that you originally observed when you brought the charged rod close to the electroscope sphere. You probably did not realize that you were performing an experiment very similar to one of the most famous experiments in the history of the study of electric fields — Michael Faraday's ice-pail experiment. Faraday devised this experiment to show that electric charge will reside only on the *outside* of a hollow conductor. The experiment is outlined schematically in Figure 8.8 and described in the steps that follow.

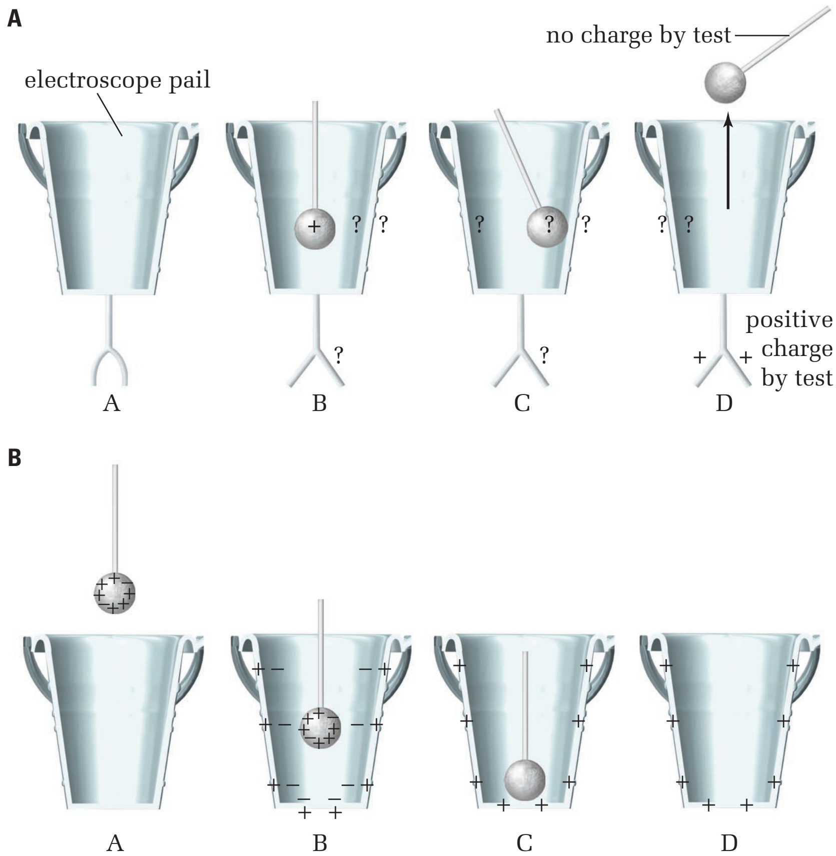

Figure 8.8 **(A)** The questions raised by Faraday's ice-pail experiment; **(B)** the answers

Faraday's Ice-Pail Experiment

- A hollow metal can (Faraday happened to use an ice pail), insulated from its surroundings, was connected to an uncharged electroscope.

- A positively charged metal ball was lowered into the pail by its insulated handle. The electroscope leaves diverged and stayed at a fixed divergence. When the metal ball was moved around inside the ice pail, the electroscope leaves stayed at a fixed angle of divergence.
- The metal ball was allowed to touch the inside of the ice pail. The angle of divergence of the leaves of the electroscope remained the same.
- The metal ball was then removed from the ice pail and the ball and the leaves were tested for charge. The ball was found to be uncharged, and the leaves were charged positively.

From his experiment, Faraday deduced the following.

- The positive ball had induced a negative charge on the inside wall of the pail and a positive charge on the outside wall.
- The induced charge was of the same magnitude as the charge on the ball, since the charges on the ball and the inside wall of the pail cancelled each other.
- The induced charges on the inside and outside walls of the pail were of equal magnitude, since the angle of divergence of the leaves did not change throughout the experiment.

Two general properties were illustrated by this experiment.

1. The formation of one charge is always accompanied by the formation of an equal, but opposite, charge.
2. The net charge in the interior of a hollow conductor is zero; all excess charge is found on the outside.

The latter property led to the general conclusion that an external electric field will not affect the inside of a hollow conductor. In fact, it will be shielded. Faraday pursued this with a further demonstration in which he built a very large metal cage, mounted on insulators, and then entered the cage to perform electrostatic experiments, while a very high electric field was generated all around him.

This electric screening was the basis of the Cover It Up activity in the Multi-Lab at the beginning of the chapter. If you charge an electroscope and then place a cage (or inverted can) over the sphere of the electroscope, you will shield it from external electric fields. If you bring a charged rod close to the cage, the leaves of the electroscope are unaffected. This principle has become a popular method for screening sensitive electric circuit elements by placing them in some form of metal cage. Today, anything that is used to shield a region from an external electric field is called a **Faraday cage**.

WEB LINK

www.mcgrawhill.ca/links/physics12

For more information about Michael Faraday, both scientific and personal, go to the above Internet site and click on **Web Links**.